



Mobile Intel® 945GME Express Chipset Graphics and Memory Controller Hub (GMCH) for Embedded Applications

Thermal Design Guide

June 2007





INFORMATION IN THIS DOCUMENT IS PROVIDED IN CONNECTION WITH INTEL® PRODUCTS. EXCEPT AS PROVIDED IN INTEL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, INTEL ASSUMES NO LIABILITY WHATSOEVER, AND INTEL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO SALE AND/OR USE OF INTEL PRODUCTS, INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT, OR OTHER INTELLECTUAL PROPERTY RIGHT.

Intel Corporation may have patents or pending patent applications, trademarks, copyrights, or other intellectual property rights that relate to the presented subject matter. The furnishing of documents and other materials and information does not provide any license, express or implied, by estoppel or otherwise, to any such patents, trademarks, copyrights, or other intellectual property rights.

Intel products are not intended for use in medical, life-saving, life-sustaining, critical control or safety systems, or in nuclear-facility applications. Intel may make changes to specifications and product descriptions at any time, without notice.

Intel may make changes to specifications and product descriptions at any time, without notice.

Designers must not rely on the absence or characteristics of any features or instructions marked "reserved" or "undefined." Intel reserves these for future definition and shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them.

The Intel® 945GME Express Chipset GMCH may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are available on request.

MPEG is an international standard for video compression/decompression promoted by ISO. Implementations of MPEG CODECs, or MPEG enabled platforms may require licenses from various entities, including Intel Corporation.

This document and the software described in it are furnished under license and may only be used or copied in accordance with the terms of the license. The information in this document is furnished for informational use only, is subject to change without notice, and should not be construed as a commitment by Intel Corporation. Intel Corporation assumes no responsibility or liability for any errors or inaccuracies that may appear in this document or any software that may be provided in association with this document. Except as permitted by such license, no part of this document may be reproduced, stored in a retrieval system, or transmitted in any form or by any means without the express written consent of Intel Corporation.

Contact your local Intel sales office or your distributor to obtain the latest specifications and before placing your product order.

Copies of documents which have an order number and are referenced in this document, or other Intel literature, may be obtained by calling 1-800-548-4725, or by visiting Intel's website at <http://www.intel.com>.

Celeron, Intel, Intel logo, Intel NetBurst, Intel NetStructure, Intel SpeedStep, Intel Xeon, Intel XScale, Pentium, Pentium II Xeon, Pentium III Xeon, and VTune are trademarks or registered trademarks of Intel Corporation or its subsidiaries in the United States and other countries.

This device is protected by U.S. patent numbers 5,315,448 and 6,516,132, and other intellectual property rights. The use of Macrovision's copy protection technology in the device must be authorized by Macrovision and is intended for home and other limited pay-per-view uses only, unless otherwise authorized in writing by Macrovision. Devices incorporating Macrovision's copy protection technology can only be sold or distributed to companies appearing on Macrovision's list of "Authorized Buyers" at: www.macrovision.com. Reverse engineering or disassembly is prohibited.

*Other names and brands may be claimed as the property of others.

Copyright © Intel Corporation 2007. All rights reserved.

Contents

1	Introduction	5
1.1	Scope	5
1.2	Terminology	5
1.3	Reference Documents.....	6
2	Product Specifications	7
2.1	Package Description	7
2.1.1	Ball Grid Array Package Ball Placement	7
2.2	Thermal Specifications	7
2.3	Thermal Design Power (TDP).....	8
2.3.1	Application Power	8
2.3.2	Specifications	8
3	Thermal Metrology.....	10
3.1	Case Temperature Measurements	10
3.1.1	Thermocouple Attach Methodology.....	10
3.2	Airflow Characterization	11
4	Reference Thermal Solution.....	13
4.1	Operating Environment and Thermal Performance	13
4.2	Mechanical Design Envelope	15
4.3	Thermal Solution Assembly.....	16
4.3.1	Heatsink Orientation	16
4.3.2	Heatsink Clip	16
4.3.3	Solder-Down Anchors.....	16
4.3.4	Thermal Interface Material (TIM).....	16
4.4	Board-Level Component Keep-outs.....	17
4.5	Environmental Reliability Requirements.....	18
Appendix A	Conclusion.....	19
Appendix B	Enabled Suppliers	20
Appendix C	Mechanical Drawings	21

Figures

Figure 1	GMCH Ball Grid Array (Bottom View)	7
Figure 2	Zero Degree Attach Methodology (Top View)	11
Figure 3	Zero Degree Attach Heatsink Modifications (Generic Heatsink)	11
Figure 4	Airflow and Ambient Temperature Measurement Locations	12
Figure 5	Aluminum Heatsink Thermal Performance	14
Figure 6	Reference Heatsink Volumetric Height	15
Figure 7	Reference Thermal Solution Assembly	16
Figure 8	Torsional Clip Heatsink Motherboard Component Keep-out	17
Figure 9	Retention Mechanism Component Keep-out Zones	18
Figure 10	Package Drawing	22
Figure 11	Heatsink Assembly	23
Figure 12	Aluminum Heatsink	24
Figure 13	Heatsink Gasket	25
Figure 14	Torsional Clip Drawing	26

Tables

Table 1	Glossary of Terms	5
Table 2	Reference Documents	6
Table 3	Case Temperature Specifications	8
Table 4	GMCH/MCH Thermal Design Power Specifications	9
Table 5	Thermal Requirements	13
Table 6	Reference Thermal Solution Environmental Reliability Requirements	18
Table 7	Reference Design Heatsink Enabled Suppliers	20
Table 8	Mechanical Drawings	21

Revision History

Date	Revision	Description
June 2007	002	Changed name to 945GME.
February 2006	001	Initial public release.

1 Introduction

The objective of thermal management is to ensure that the temperatures of all components in a system are maintained within functional limits. The functional temperature limit is the range within which the electrical circuits can be expected to meet specified performance requirements. Operation outside the functional limit can degrade system performance, cause logic errors, or cause component and/or system damage. Temperatures exceeding the maximum operating limits may result in irreversible changes in the operating characteristics of the component. The goal of this document is to provide an understanding of the operating limits of the Mobile Intel® 945GME Express Chipset Graphics and Memory Controller Hub (GMCH) and discuss a reference thermal solution.

The simplest and most cost-effective method to improve the inherent system cooling characteristics of the GMCH is through careful design and placement of fans, vents, and ducts. When additional cooling is required, component thermal solutions may be implemented in conjunction with system thermal solutions. The GMCH will require a heatsink to maintain the component temperature specifications.

1.1 Scope

This document presents conditions and requirements to properly design a cooling solution for systems that implement the Mobile Intel® 945GME Express Chipset GMCH. Specifically, it applies to implementation in embedded applications and form factors. Properly designed thermal solutions provide adequate cooling to maintain the GMCH case temperature at or below thermal specifications. This is accomplished by providing a low local-ambient temperature, ensuring adequate airflow, and minimizing case-to-local-ambient thermal resistance. By maintaining the GMCH case temperature at or below the specifications, a system designer can ensure the proper functionality, performance, and reliability of the chipset.

1.2 Terminology

Table 1 Glossary of Terms

Term	Description
BGA	Ball Grid Array. A package type defined by a resin-fiber substrate where a die is mounted and bonded. The primary electrical interface is an array of solder balls attached to the substrate opposite the die and molding compound.
FC-BGA	Flip Chip Ball Grid Array. A package type defined by a plastic substrate where a die is mounted using an underfill C4 (Controlled Collapse Chip Connection) attach style. The primary electrical interface is an array of solder balls attached to the substrate opposite the die. Note that the device arrives at the customer with solder balls attached.
Intel® ICH7M	Intel® Mobile I/O Controller Hub 7. The chipset component that contains the primary PCI Express interface, LPC interface, USB, ATA, and/or other legacy functions.
Intel® ICH7M-DH	Digital Home version of the Intel® Mobile I/O Controller Hub 7. In addition to the features of the regular ICH7M the Digital Home SKU adds RAID functionality and two additional PCI Express ports.
mBGA	Mini Ball Grid Array. A smaller version of the BGA.

Term	Description
GMCH	Graphic Memory Controller Hub. The chipset component that contains the processor and memory interface and integrated graphics core.
T_A	The measured ambient temperature locally to the component of interest. The ambient temperature should be measured just upstream of airflow for a passive heatsink or at the fan inlet for an active heatsink. Also referred to a T_{LA} .
T_C	The measured case temperature of a component. For processors, it is measured at the geometric center of the integrated heat spreader (IHS). For other component types, it is generally measured at the geometric center of the die or case.
T_{C-MAX}	The maximum case/die temperature with an attached heatsink. This temperature is measured at the geometric center of the top of the package case/die.
T_{C-MIN}	The minimum case/die temperature with an attached heatsink. This temperature is measured at the geometric center of the top of the package case/die.
TDP	Thermal Design Power is specified as the highest sustainable power level of most or all of the real applications expected to be run on the given product, based on extrapolations in both hardware and software technology over the life of the component. Thermal solutions should be designed to dissipate this target power level.
TIM	Thermal Interface Material: thermally conductive material installed between two surfaces to improve heat transfer and reduce interface contact resistance.
LFM	Linear Feet per Minute. Unit of airflow speed.
CFM	Cubic Feet per Minute. Volumetric fluid flow rate.
Ψ_{CA}	Case-to-ambient thermal characterization parameter ("psi"). A measure of thermal solution performance using total package power. Defined as $(T_C - T_A) / \text{Total Package Power}$. Heat source size needs to be specified for Ψ measurements.
Ψ_{SA}	Sink-to-Ambient thermal characterization parameter ("psi"). A measure of the heatsink performance using total package power. Defined as $(T_S - T_A) / \text{Total Package Power}$. Heat source size needs to be specified for Ψ measurements.
Ψ_{CS}	Case-to-Sink thermal characterization parameter ("psi"). A measure of the thermal interface materials performance. Defined as $(T_C - T_S) / \text{Total Package Power}$. Heat source size need to be specified for Ψ measurements.

1.3 Reference Documents

Table 2 Reference Documents

Document	Comments
Mobile Intel® 945 Express Chipset Family Datasheet	http://developer.intel.com/design/mobile/datashts/309219.htm
Intel® I/O Controller Hub 7 (ICH7) Thermal Design Guide	http://www.intel.com/design/chipsets/designex/307015.htm

2 Product Specifications

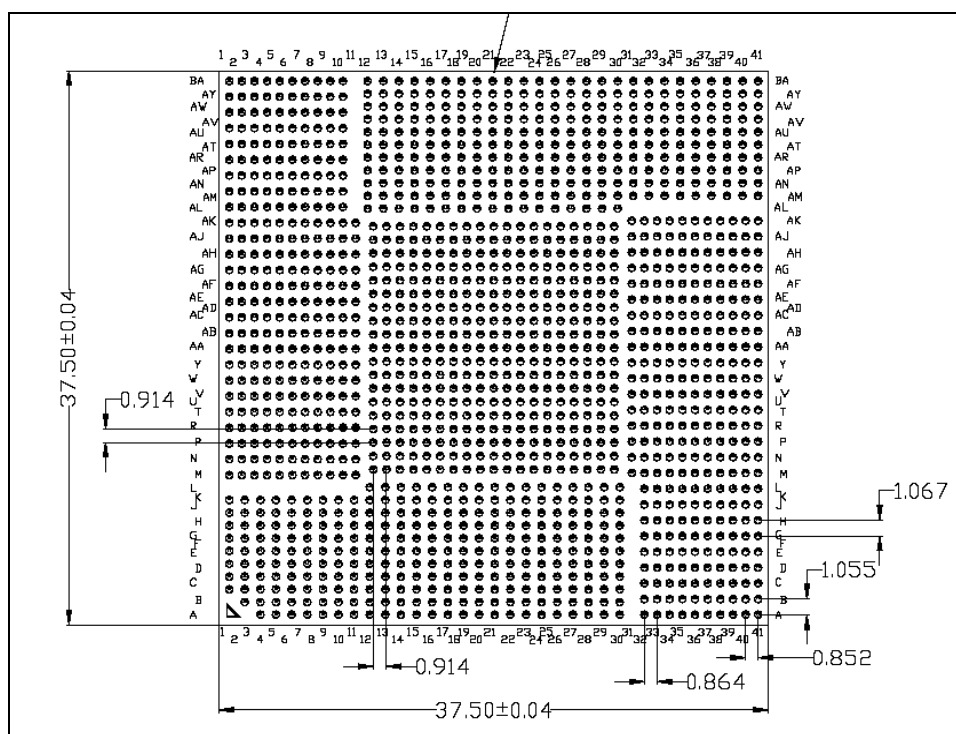
2.1 Package Description

The Mobile Intel® 945GME Express Chipset GMCH is available in a 37.5 mm [1.48 in] x 37.5 mm [1.48 in] Flip Chip Ball Grid Array (FC-BGA) package with 1466 solder balls. The die size is 10.55 mm [0.415 in] x 10.44 mm [0.411 in] and is subject to change. A mechanical drawing of the package is shown in Appendix B.

2.1.1 Ball Grid Array Package Ball Placement

The GMCH package has a solder ball pattern as shown in Figure 1. Board designers should ensure correct ball placement when designing for the grid array pattern. For exact ball locations relative to the package, refer to the *Mobile Intel® 945 Express Chipset Family Datasheet*.

Figure 1 GMCH Ball Grid Array (Bottom View)



2.2 Thermal Specifications

To ensure proper operation and reliability of the GMCH, the temperature must be at or below the maximum value specified in Table 3. System and component level thermal enhancements are required to dissipate the heat generated and maintain the GMCH within specifications. Section 3 provides the thermal metrology guidelines for case temperature measurements.

The GMCH should also operate above the minimum case temperature specification (T_{C-MIN}) listed in Table 3.

Table 3 Case Temperature Specifications

Parameter	Value
T_{C-MAX}	105 °C
T_{C-MIN}	0 °C

NOTE: Thermal specifications assume an attached heatsink is present.

2.3 Thermal Design Power (TDP)

Thermal design power (TDP) is the estimated power dissipation of the GMCH based on normal operating conditions including V_{CC} and T_{C-MAX} while executing real worst-case power intensive applications. This value is based on expected worst-case data traffic patterns and usage of the chipset and does not represent a specific software application. TDP attempts to account for expected increases in power due to variation in chipset current consumption due to silicon process variation, processor speed, DRAM capacitive bus loading and temperature. However, since these variations are subject to change the TDP cannot guarantee that all applications will not exceed the TDP value.

The system designer must design a thermal solution for the GMCH such that it maintains T_C below T_{C-MAX} for a sustained power level equal to TDP. The TDP value can be used for thermal design if the chipset thermal protection mechanisms are enabled. Intel chipsets incorporate a hardware-based fail-safe mechanism to keep the product temperature in spec in the event of unusually strenuous usage above the TDP power.

The GMCH provides a hardware-based mechanism to reduce GMCH power by limiting the traffic that occurs to certain interfaces. Traffic limits are programmed into the chipset registers during system boot as part of the Intel-supplied BIOS reference code. For more information on hardware-based fail-safe mechanisms, refer to the *Mobile Intel® 945 Express Chipset Family Datasheet*.

2.3.1 Application Power

Designing to the TDP can ensure a particular thermal solution can meet the cooling needs of future applications. Testing with currently available commercial applications has shown they may dissipate power levels below the published TDP specification in Section 2.3.2. Intel strongly recommends that thermal engineers design to the published TDP specification to develop a robust thermal solution that will meet the needs of current and future applications.

2.3.2 Specifications

The GMCH is estimated to dissipate the Thermal Design Power values for the various configurations provided in Table 4. FC-BGA packages have poor heat transfer capability into the board and have minimal thermal capability without thermal solutions. Intel requires that system designers plan for an attached heatsink when using the GMCH.



Table 4 GMCH/MCH Thermal Design Power Specifications

Configuration	Front Side Bus Frequency (MHz)	soDIMMs	Memory Type	Internal Graphics Frequency (MHz)	DMI	V _{CC}	TDP (W)
Dual Channel	533	2	DDR2 - 400 MHz	166	x 4	1.05 V	5.8
Dual Channel	667	2	DDR2 - 533 MHz	Discrete	x 4	1.05 V	5.9
Dual Channel	667	2	DDR2 - 667 MHz	Discrete	x 4	1.05 V	6.1
Dual Channel	667	2	DDR2 - 533 MHz	250	x 4	1.05 V	6.9
Dual Channel	667	2	DDR2 - 667 MHz	250	x 4	1.05 V	7.0

3 Thermal Metrology

The system designer must measure temperatures in order to accurately determine the thermal performance of the system. Intel has established guidelines for proper techniques of measuring chipset component case and ambient temperatures.

3.1 Case Temperature Measurements

To ensure functionality and reliability, the chipset GMCH is specified for proper operation when T_C is maintained at or below the maximum temperature listed in Table 3. The surface temperature at the geometric center of the die corresponds to T_C . Measuring T_C requires special care to ensure an accurate temperature reading.

Temperature differences between the temperature of a surface and the surrounding local ambient air can introduce error in the measurements. The measurement errors could be due to a poor thermal contact between the thermocouple junction and the surface of the package, heat loss by radiation and/or convection, conduction through thermocouple leads, or contact between the thermocouple cement and the heatsink base (if a heatsink is used). To minimize these measurement errors, a thermocouple attach with a zero degree methodology is recommended.

The following section details the modifications required to measure package case temperature using a clip-attached heatsink. The reference thermal solutions presented in this document use a clip-attach mechanism.

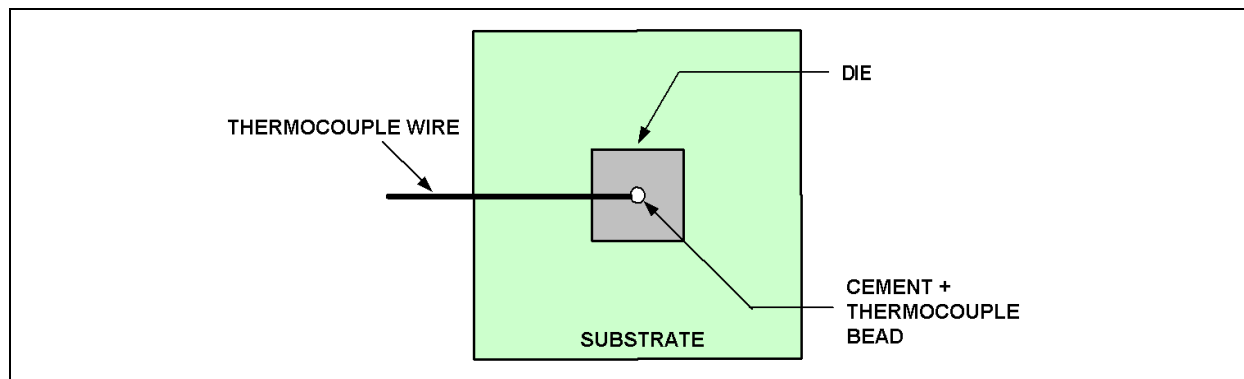
3.1.1 Thermocouple Attach Methodology

1. Mill a 3.3 mm [0.13 in.] diameter hole centered on the bottom of the heatsink base. The milled hole should be approximately 1.5 mm [0.06 in.] deep as shown in Figure 3.
2. Mill a 1.3 mm [0.05 in.] wide slot, 0.5 mm [0.02 in.] deep, from the centered hole to one edge of the heatsink. The slot should be in the direction parallel to the heatsink fins (see Figure 3).
3. Attach thermal interface material (TIM) to the bottom of the heatsink base.
4. Cut out portions of the TIM to make room for the thermocouple wire and bead. The cutouts should match the slot and hole milled into the heatsink base.
5. Attach a 36-gauge or smaller calibrated K-type thermocouple bead or junction to the center of the top surface of the die using a high thermal conductivity cement. During this step, make sure no contact is present between the thermocouple cement and the heatsink base because any contact will affect the thermocouple reading.

Caution: It is critical that the thermocouple bead makes contact with the die (see Figure 2).

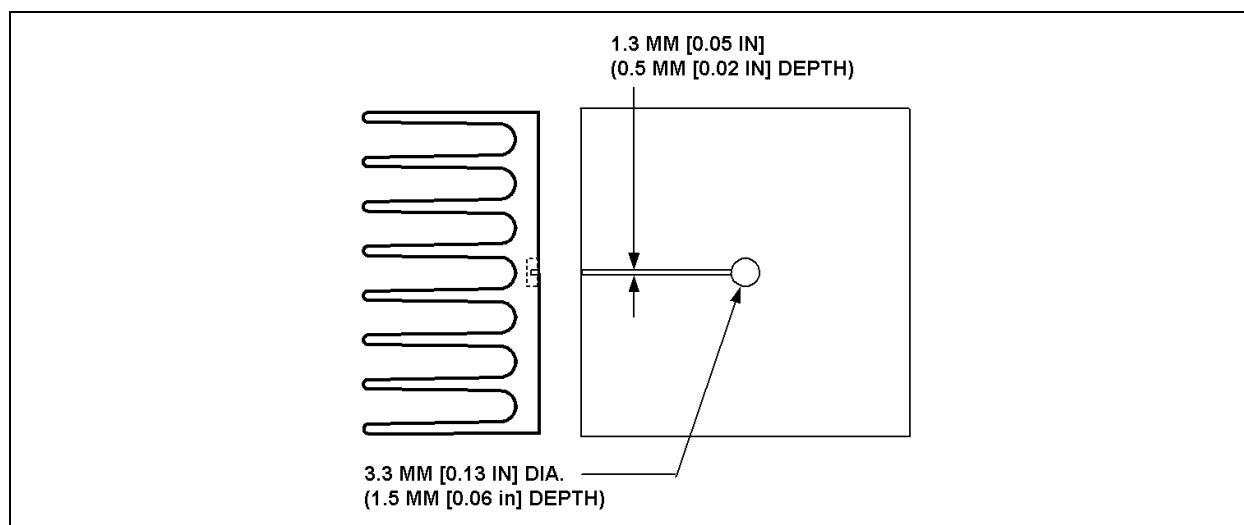
6. Attach the heatsink assembly to the GMCH, and route thermocouple wires out through the milled slot. Following the guidelines is critical to ensure an accurate and repeatable metrology.

Figure 2 Zero Degree Attach Methodology (Top View)



NOTE: Drawing not to scale.

Figure 3 Zero Degree Attach Heatsink Modifications (Generic Heatsink)

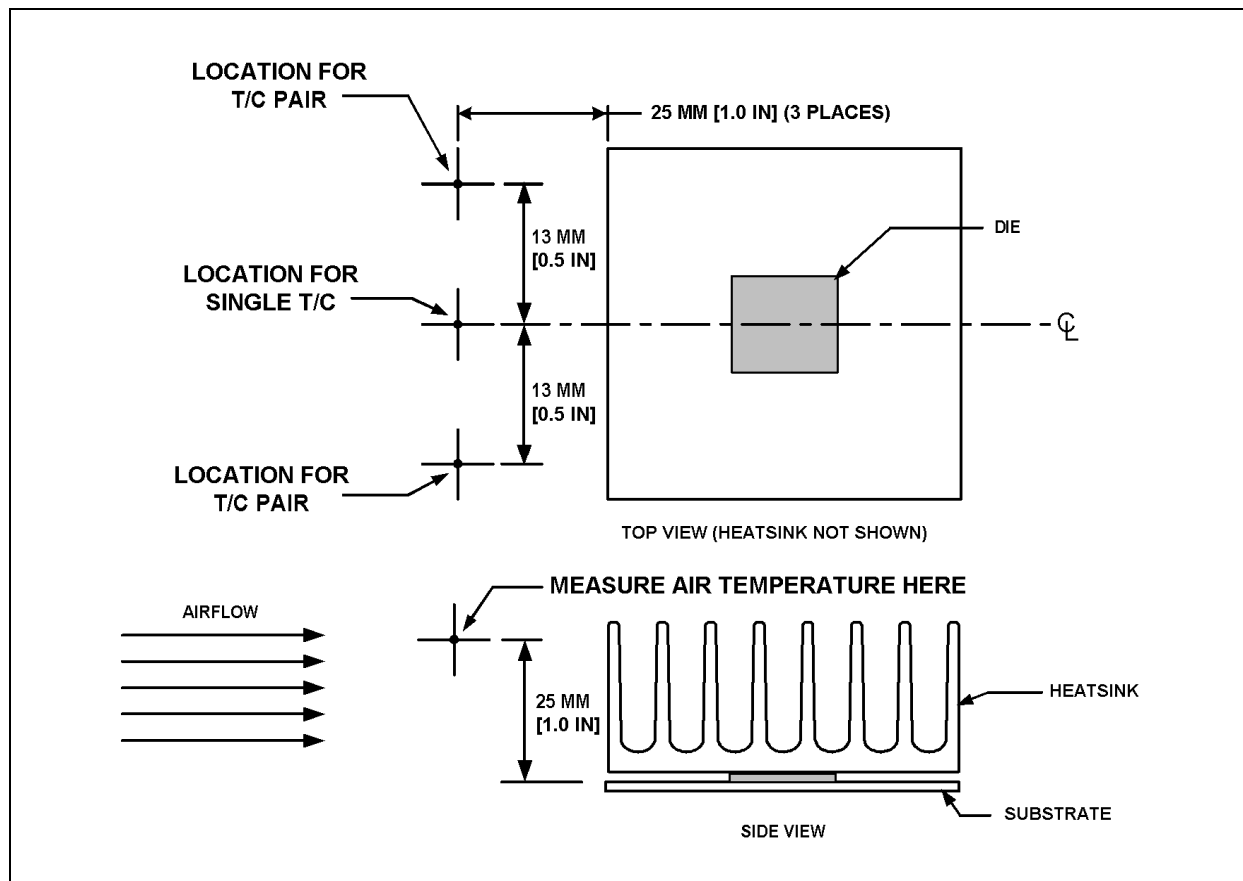


NOTE: Drawing not to scale.

3.2 Airflow Characterization

Figure 4 describes the recommended location for air temperature measurements measured relative to the component. For a more accurate measurement of the average approach air temperature, Intel recommends averaging temperatures recorded from two thermocouples spaced about 25 mm [1 in.] apart. Locations for both a single thermocouple and a pair of thermocouples are presented.

Figure 4 Airflow and Ambient Temperature Measurement Locations



Airflow velocity should be measured using industry standard air velocity sensors. Typical airflow sensor technology may include hot wire anemometers.

Figure 4 provides guidance for airflow velocity measurement locations. These locations are for a typical JEDEC test setup and may not be compatible with chassis layouts due to the proximity of the processor to the GMCH. The user may have to adjust the locations for a specific chassis.

Be aware that sensors may need to be aligned perpendicular to the airflow velocity vector or an inaccurate measurement may result.

Measurements should be taken with the chassis fully sealed in its operational configuration to achieve a representative airflow profile within the chassis.

4 Reference Thermal Solution

Intel has developed an embedded reference thermal solution designed to meet the cooling needs of the Mobile Intel® 945GME Express Chipset GMCH. This chapter describes the overall requirements for the reference thermal solution including critical-to-function dimensions, operating environment, and validation criteria. The other components of the chipset may or may not need attached thermal solutions, depending on your specific system local-ambient operating conditions.

For more information on the Intel® Mobile I/O Controller Hub 7 (ICH7M), refer to the *Intel® I/O Controller Hub 7 (ICH7) Family Thermal Design Guide*.

4.1 Operating Environment and Thermal Performance

Reference thermal solutions have been designed for the 945GME GMCH. This document will describe the reference heatsink for the GMCH for the 1U/2U server form factor and AdvancedTCA* form factor (see Figure 12). This solution may be suitable for other form factors, but system integrators need to validate the entire thermal solution in end user conditions.

The reference thermal solution was designed assuming a maximum local ambient air temperature (T_{LA}) of 55° C. The required minimum airflow velocity directly upstream of the heatsink varies depending on the GMCH configuration and the resulting TDP. Assuming these boundary conditions are met, the reference thermal solutions will meet the thermal specifications for the GMCH. Table 5 shows the required thermal performance for the GMCH in the lowest and highest TDP configurations.

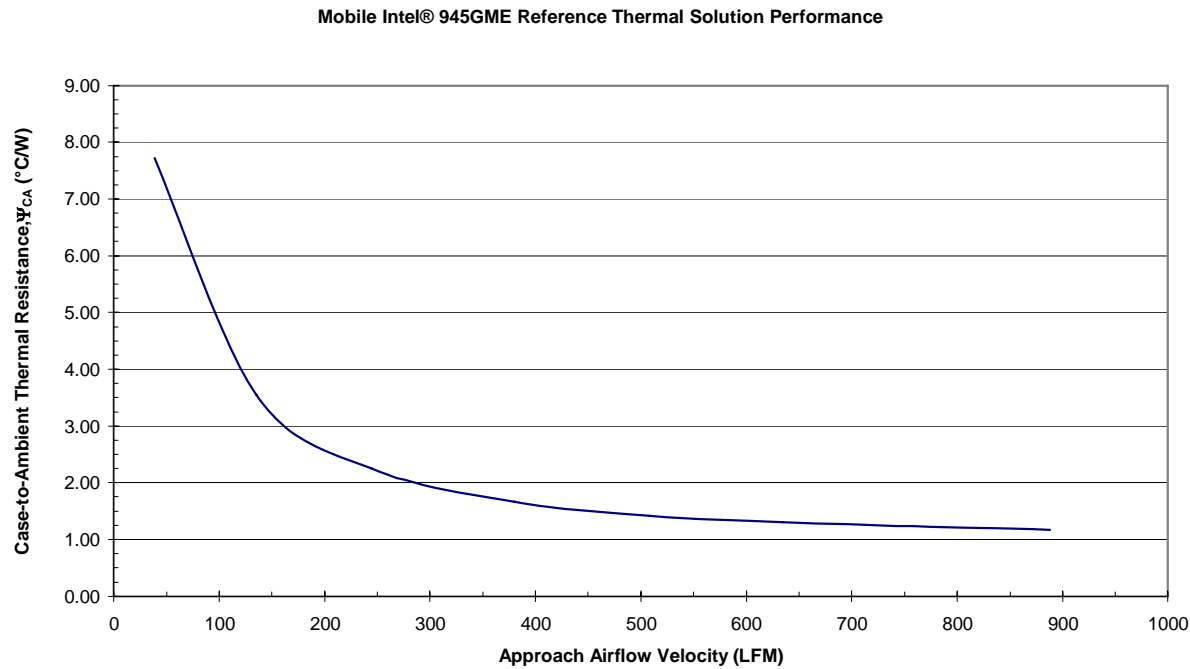
Table 5 Thermal Requirements

TDP (W)	Required Ψ_{CA} (°C/W) at $T_{LA} = 55^{\circ} \text{C}$
5.8	8.62
7.0	7.14

The thermal performance of the reference thermal solution for the GMCH is shown in Figure 5. This figure shows the performance of the reference thermal solution at sea level based on lab test data. It is important to note that this data does not imply any statistical significance. System integrators must validate the entire thermal solution in its final intended end use.



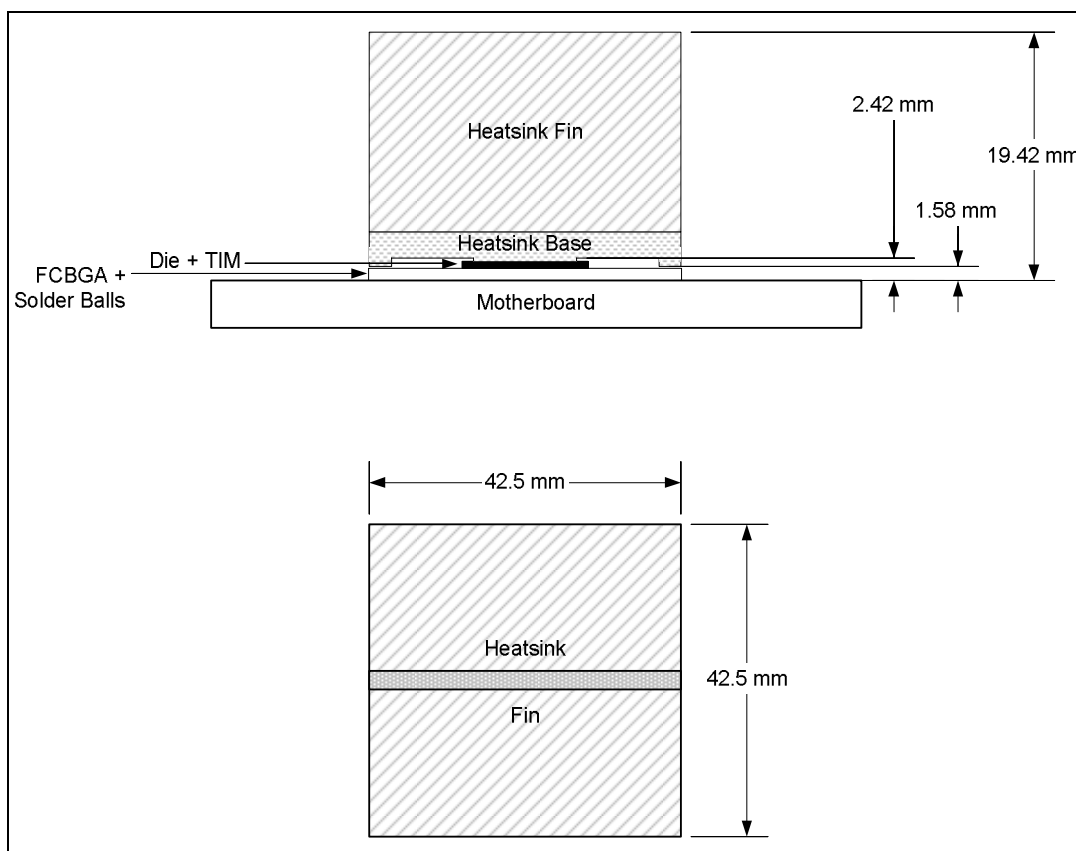
Figure 5 Aluminum Heatsink Thermal Performance



4.2 Mechanical Design Envelope

The motherboard component keep-out restrictions for the 1U/2U and AdvancedTCA* thermal solution are included in Section 4.4. Figure 6 shows the reference heatsink volumetric constraints. This heatsink extends 19.42 mm [0.675 in.] nominally above the board when mounted. System integrators should ensure no board or chassis components would intrude into the volume occupied by the heatsink. This solution does not occupy the maximum allowed space above the motherboard for the 1U and 2U server form factors. The maximum component height above the board is delineated in the Thin Electronics Bay specification located at www.ssiforum.org. The maximum component height above the board for the AdvancedTCA form factor is stated in the AdvancedTCA specifications at www.picmg.org.

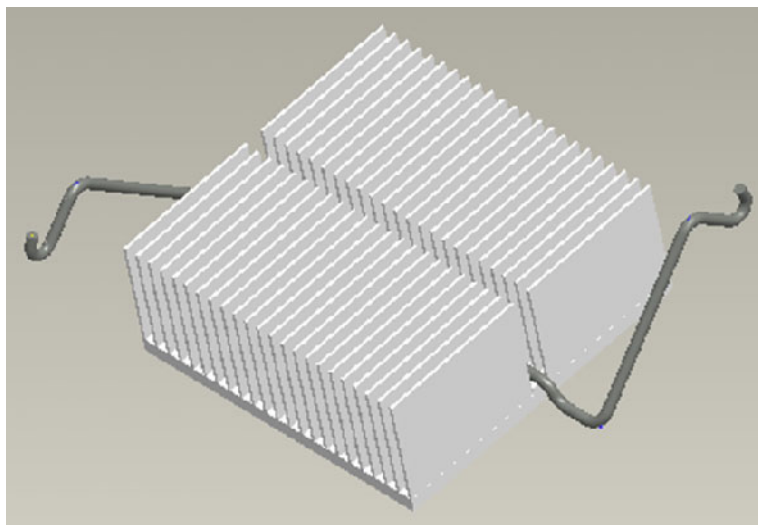
Figure 6 Reference Heatsink Volumetric Height



4.3 Thermal Solution Assembly

The reference thermal solution will consist of a passively cooled aluminum heatsink. The heatsink is comprised of an extruded or skived aluminum heatsink attached to the motherboard by a torsional clip and anchors soldered to the board. The thermal interface material for this heatsink (Honeywell* PCM45F) is pre-applied to the heatsink bottom over an area in contact with the package die. The heatsink assembly can be seen in Figure 7.

Figure 7 Reference Thermal Solution Assembly



4.3.1 Heatsink Orientation

The GMCH heatsink is a uni-directional fin heatsink. This type of heatsink design requires that the fins must be aligned with the direction of the airflow.

4.3.2 Heatsink Clip

The reference thermal solution uses a wire clip with hooked ends. The hooks attach to wire anchors to fasten the heatsink to the board. The mechanical drawing of the clip is located in Appendix B.

4.3.3 Solder-Down Anchors

For platforms that have very limited board space, a clip retention solder-down anchor has been developed to minimize the impact of clip retention on the board. It is based on a standard three-pin jumper and is soldered to the board like any common through-hole header. A new anchor design is available with 45° bent leads to increase the anchor attach reliability over time. The part number and vendor information is contained in Appendix A.

4.3.4 Thermal Interface Material (TIM)

A thermal interface material provides improved conductivity between the die and heatsink. It is important to understand and consider the impact of the interface between the die and heatsink base

on the overall thermal solution. Specifically, the bond line thickness, interface material area, and interface material thermal conductivity must be selected to optimize the thermal solution.

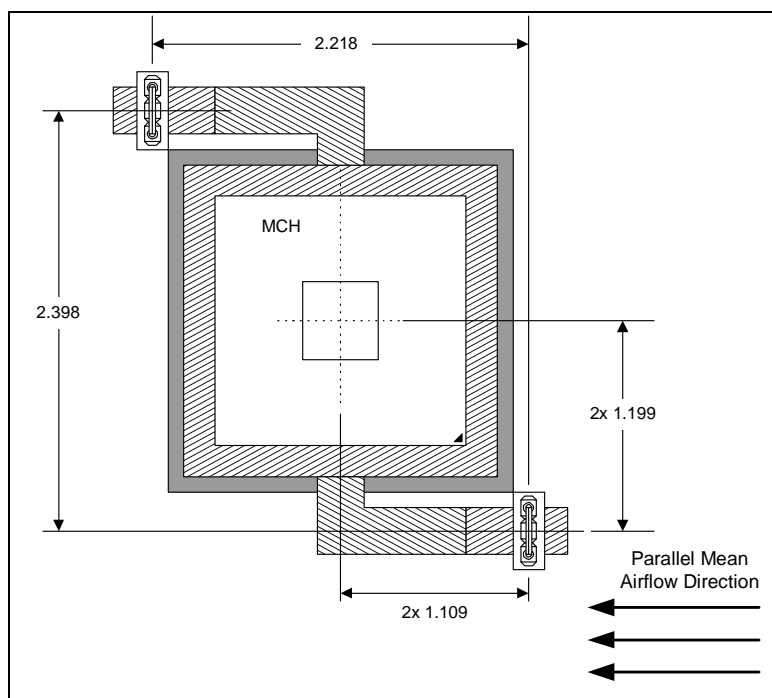
It is important to minimize the thickness of the TIM, commonly referred to as the bond line thickness. A large gap between the heatsink base and the die yields a greater thermal resistance. The thickness of the gap is determined by the flatness of both the heatsink base and the die, plus the thickness of the TIM, and the clamping force applied by the heatsink attachment method. To ensure proper and consistent thermal performance, the TIM and application process must be properly designed.

The GMCH reference thermal solution uses Honeywell PCM45F. Alternative materials can be used at the user's discretion. Regardless, the entire heatsink assembly, including the heatsink, TIM, and attach method must be validated for specific applications.

4.4 Board-Level Component Keep-outs

The locations of the hole patterns and motherboard component keep-outs for the GMCH can be seen in Figure 8 and Figure 9. Dimensions are in inches.

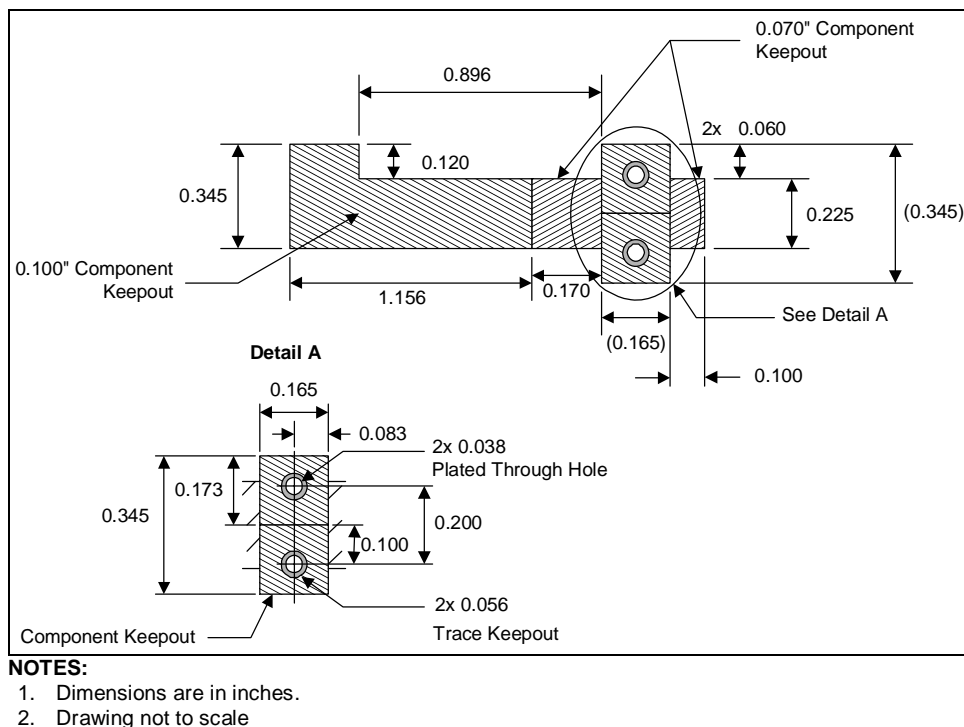
Figure 8 Torsional Clip Heatsink Motherboard Component Keep-out



NOTES:

1. Dimensions are in inches.
2. Drawing not to scale

Figure 9 Retention Mechanism Component Keep-out Zones



4.5 Environmental Reliability Requirements

The environmental reliability requirements for the reference thermal solution are shown in Table 6. These should be considered as general guidelines. Validation test plans should be defined by the user based on anticipated use conditions and resulting reliability requirements.

Table 6 Reference Thermal Solution Environmental Reliability Requirements

Test ¹	Requirement	Pass/Fail Criteria ²
Mechanical Shock	<ul style="list-style-type: none"> • Three drops for + and - directions in each of three perpendicular axes (i.e., total 18 drops). • Profile: 50 G trapezoidal waveform, 11 ms duration, 4.3 m/s [170 in/s] minimum velocity change. • Setup: Mount sample board on test fixture. Include 450 g processor heatsink. 	Visual/Electrical Check
Random Vibration	<ul style="list-style-type: none"> • Duration: 10 min/axis, three axes • Frequency Range: 5 Hz to 500 Hz • Power Spectral Density (PSD) Profile: 3.13 g RMS 	Visual/Electrical Check
Thermal Cycling	<ul style="list-style-type: none"> • -40° C to +85° C, 1000 cycles 	Visual Check
Temperature Life	<ul style="list-style-type: none"> • 85° C, 1000 hours total 	Visual/Electrical Check
Unbiased Humidity	<ul style="list-style-type: none"> • 85% relative humidity / 55° C, 1000 hours 	Visual Check

NOTES:

1. Tests should be performed on a sample size of at least 12 assemblies from three different lots of material.
2. Additional pass/fail criteria may be added at the discretion of the user.

5 Conclusion

As the complexity of computer systems increases, so do power dissipation requirements. The additional power of next generation systems must be properly dissipated. Heat can be dissipated using improved system cooling, selective use of ducting, and/or passive heatsinks.

The simplest and most cost-effective method to improve the inherent system cooling characteristics of the GMCH is through careful design and placement of fans, vents, and ducts. When additional cooling is required, component thermal solutions may be implemented in conjunction with system thermal solutions. The size of the fan or heatsink can be varied to balance size and space constraints with acoustic noise.

This document has presented the conditions and requirements to properly design a cooling solution for systems that implement the GMCH. Properly designed solutions provide adequate cooling to maintain the GMCH case temperature at or below thermal specifications. This is accomplished by providing a low local-ambient temperature, ensuring adequate local airflow, and minimizing the case to local-ambient thermal resistance. By maintaining the case temperature at or below those recommended in this document, a system designer can ensure the proper functionality, performance, and reliability of this chipset.

Appendix A Enabled Suppliers

Enabled suppliers for the reference thermal solution are listed in Table 7.

Table 7 Reference Design Heatsink Enabled Suppliers

Part	Intel Part Number	Supplier	Contact Information
Aluminum Heatsink (see note)	N/A	CoolerMaster*	Wendy Lin (USA) 510-770-8566 ext 211 wendy@coolermaster.com
Thermal Interface (PCM45F)	N/A	Honeywell*	Paula Knoll 858-279-2956 Paula.knoll@honeywell.com
Heatsink Attach Clip	A69230-001	CCI/ACK*	Harry Lin (USA) 714-739-5797 hlinack@aol.com Monica Chih (Taiwan) 866-2-29952666, x1131 Monica_chih@ccic.com.tw
		Foxconn*	Jack Chen 714-626-1233 jack.chen@foxconn.com
Solder-Down Anchor	A13494-005	Foxconn	Julia Jiang (USA) 408-919-6178 juliaj@foxconn.com
NOTE: Heatsink drawings may be delivered to any heatsink manufacturer for piece parts.			

Note: These vendors and devices are listed by Intel as a convenience to Intel's general customer base, but Intel does not make any representations or warranties whatsoever regarding quality, reliability, functionality, or compatibility of these devices. This list and/or these devices may be subject to change without notice.

Appendix B Mechanical Drawings

The following table lists the mechanical drawings contained in this appendix.

Table 8 Mechanical Drawings

Drawing Name	Page Number
Package Drawing	22
Heatsink Assembly	23
Aluminum Heatsink	24
Heatsink Gasket	25
Torsional Clip Drawing	26

Notes:

- DIE SIZE IS X=10.55 Y=10.44 AND DIE OFFSET IS X=0 Y=0.0743
- THIS IS A CAPACITOR AREA, HANDLING KEEP OUT ZONE.
- THIS IS A HANDLING AREA, PACKAGE KEEP OUT ZONE.
- ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED ARE IN MILLIMETER
- PLEASE VERIFY BALL LOCATIONS WITH THE X,Y BALL COORDINATES THAT CAN BE OBTAINED FROM YOUR INTEL REPRESENTATIVE.

The drawing includes three main views:

- TOP VIEW:** Shows the square footprint of the package with dimensions 7.000 mm by 5.000 mm. It features a central die area with a crosshair pattern and four corner pads. Callout 1 points to the top edge, callout 2 to the right edge, and callout 3 to the bottom edge.
- SIDE VIEW (UNMOUNTED PKG):** Shows the profile of the package. The substrate thickness is 1.08 ± 0.06 mm. The die is mounted on the substrate with a height of 0.074 mm (see Note #2). The die has a width of 1.920 mm. Callout 4 points to the substrate, callout 5 to the die, and callout 6 to the solder bump.
- BOTTOM VIEW PKG:** Shows the underside of the package with a grid of solder balls. Dimensions include 37.50 ± 0.04 mm for the ball array size, 0.9144 mm for the pitch, and various individual ball dimensions like 0.8516 mm, 0.6970 mm, and 0.4350 mm. Callout 7 points to the ball array, callout 8 to the pitch, and callout 9 to the individual ball dimensions.

DETAIL "A"
SCALE 5:1
SOLDER RESIST OPENING (SRO)
X±0.1
Y±0.1
Z±0.1
ANGLES ±1.0°

DETAIL "B"
SCALE 5:1
UNDERFILL EPOXY
DIE SOLDER BUMPS
BGA LAND
1466 Places

DETAIL "C"
SCALE 5:1
BGA SOLDER BALLS
0.400 ± 0.10 (Ball Height)

REVISION HISTORY		DATE	APPROVED
01	PRELIMINARY RELEASE	06/06/04	
02	OUTER ROW PADS MOVED 12UM INWARD	08/19/04	
03	ADDED BALL LOCATION DIMENSION DETAILS	04/25/05	

UNLESS OTHERWISE SPECIFIED:
INTERPRET DIMENSIONS AND TOLERANCES IN ACCORDANCE WITH ASME Y14.5M-1994.
DIMENSIONS ARE IN MILLIMETERS
TOLERANCE: .X±0.1
ANGLES ±1.0°

MATERIAL: THIRD ANGLE PROJECTION
FINISH: DIBOND

DESIGNED BY: DATE:
DRAWN BY: DATE:
CHECKED BY: DATE:
APPROVED BY: DATE:

DESCRIPTION:
1466 FCBGA, 37.5MM, 6 layer
0.8mm ball pitch
Customer Mechanical Drawing

SIZE/CAGE CODE: DITBD
DRAWING NUMBER: SCALE: 6.000 DO NOT SCALE DRAWING SHEET 1 OF 1

Figure 11 Heatsink Assembly

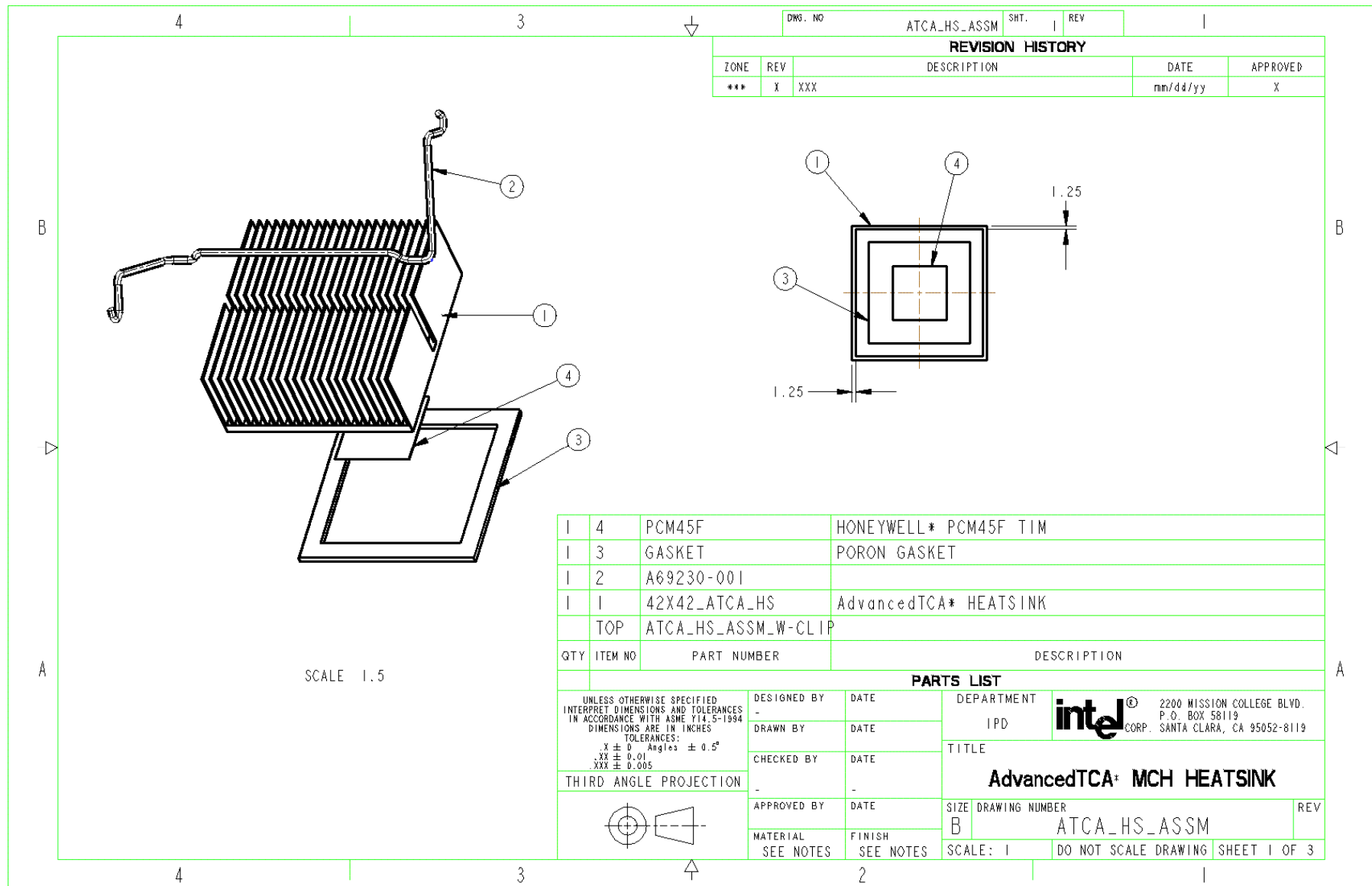


Figure 12 Aluminum Heatsink

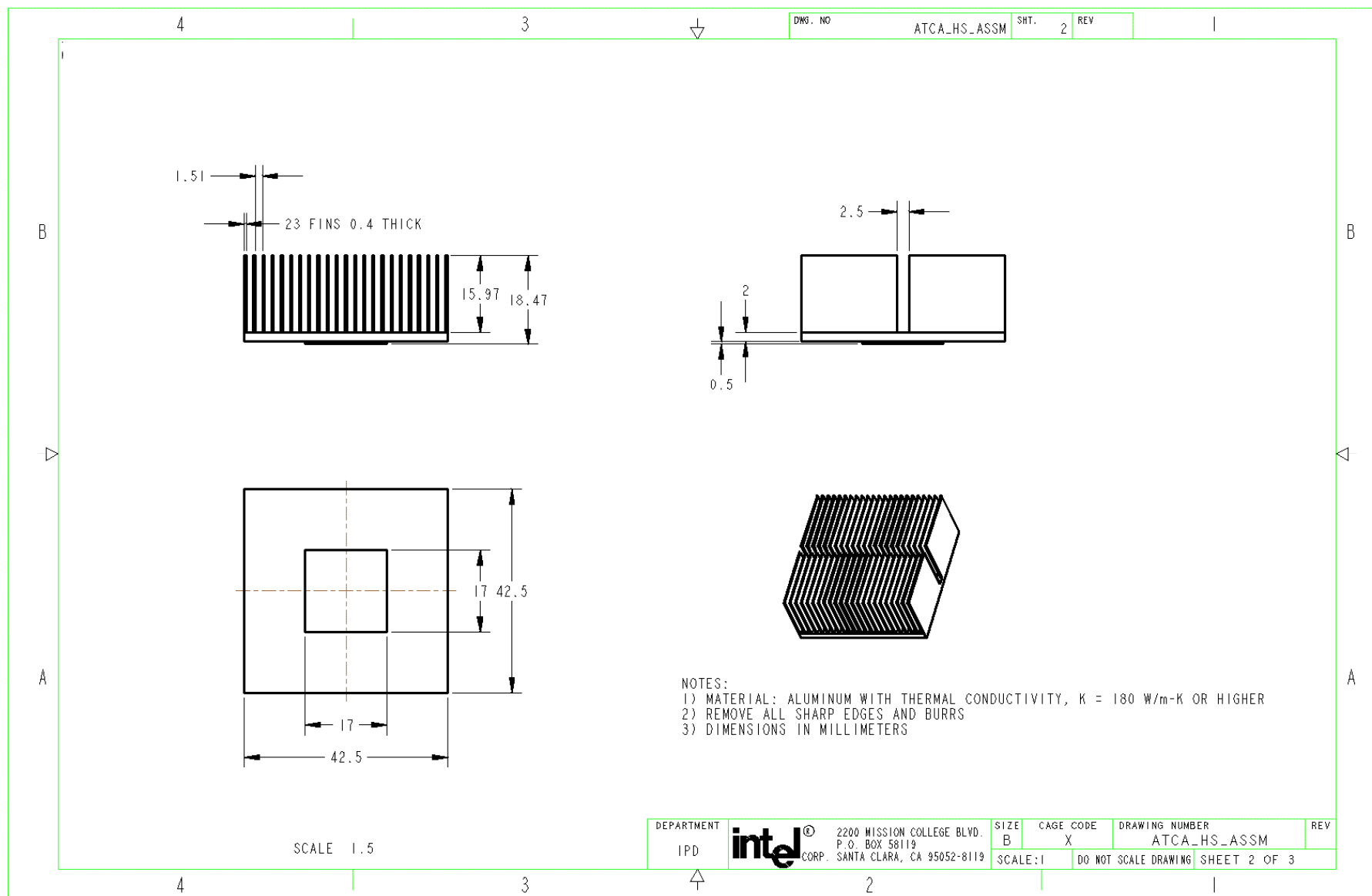


Figure 13 Heatsink Gasket

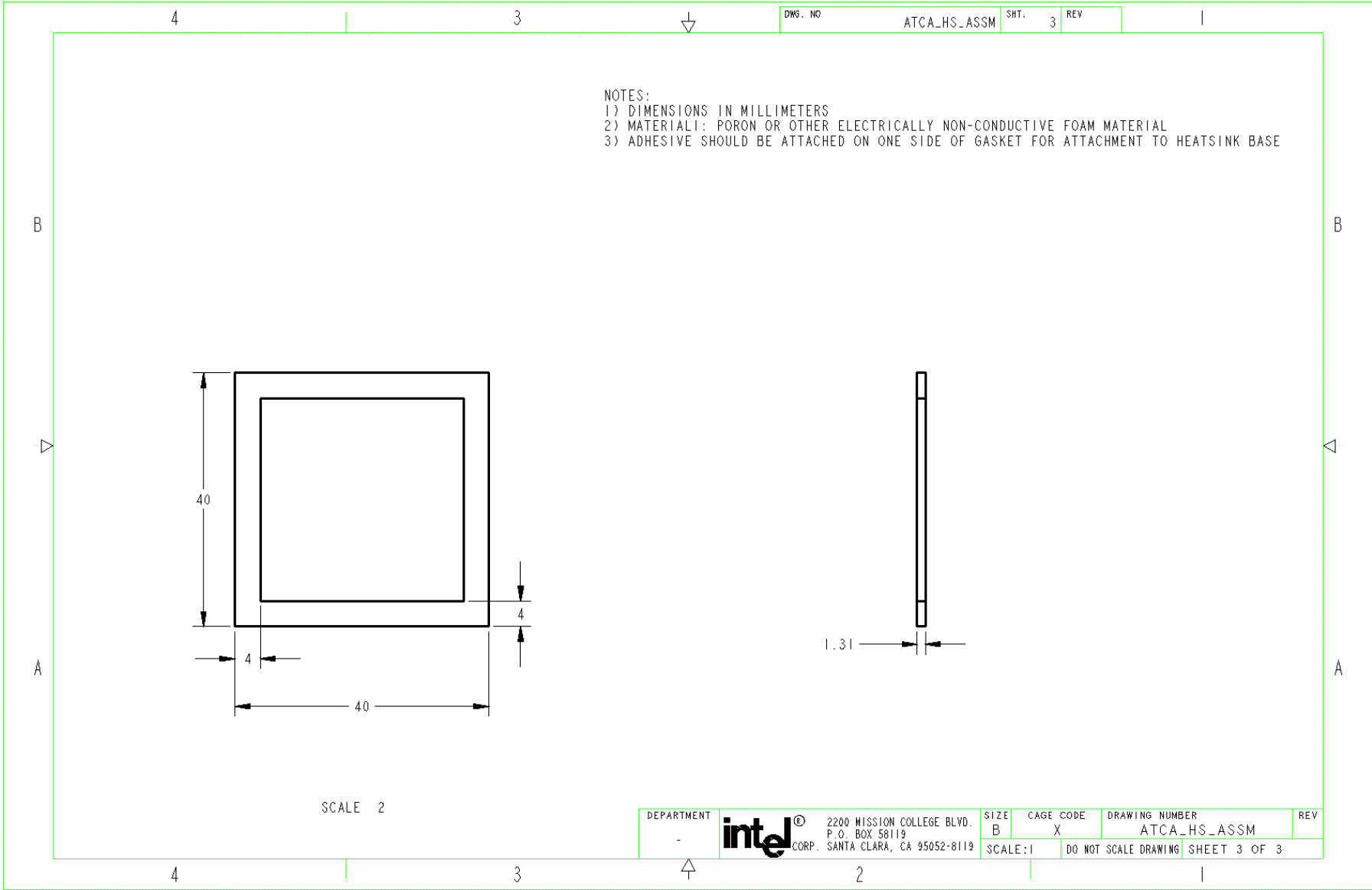


Figure 14 Torsional Clip Drawing

